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ALTITUDE SIMULATION BY TEST CELL 1-42B DURING ROCKET MOTOR FIRINGS OF SHORT DURATION

JOHN DENKER

MARCH 1969

TECHNICAL REPORT AFRPL-TR-69-95

This Technical Report has been reviewed and approved.

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AIR FORCE ROCKET PROPULSION LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
EDWARDS, CALIFORNIA

AFRPL-TR-69-95

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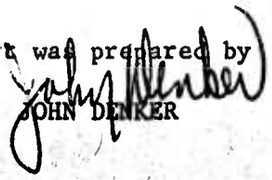
John Denker

FOREWORD

The propulsion research operations described in this report were authorized by the Air Force Rocket Propulsion Laboratory as part of the Liquid Rocket Division's Project 305803ARX. This project provides the funds and manpower required to maintain and operate the Laboratory's altitude simulation facility (1-42B) for research firings of rocket propulsion systems having up to 50,000 lb thrust, including those which utilize toxic propellants. The test item propellant grains were procured by the Solid Propellant Division by contracting with aerospace industry suppliers. The firings of this report were completed during January-March 1969. Charles Beckman (RPMCP) and John Denker (RPRO) were the project engineers for the motors and for the test operations efforts, respectively. Motor performance will be analyzed and reported by RPMCP.

This Technical Report was prepared by



JOHN DENKER

ABSTRACT

Twelve rocket motor firings were performed to determine propulsion efficiencies of two propellant formulations at high expansion ratios because the rocket exhaust gases produced by different propellant formulations will behave uniquely when expanded to the low pressure of high altitudes and may, therefore, provide varying propulsion efficiencies. These efficiencies may differ from the efficiencies of sea level firings at lower expansion ratios. It is obviously important that the delivered performance of a propellant at high altitude be known for system design calculations.

The altitude simulation facility provided pressure altitudes above 100,000 feet, and all motor firings were successful.

ABBREVIATIONS

AFRPL	Air Force Rocket Propulsion Laboratory
BATES	Ballistic Test Evaluation System
H	Pressure Altitude, feet above sea level
P_t	Pressure, total, (combustion pressure), psia
RPMCP	Rocket Propulsion Motors Propellant Development
RPRO	Rocket Propulsion Research Operations, Liquid Rocket Division of AFRPL
VTC 1-42B	Vertical Test Cell, 1-42 Space Simulation Facility

I. INTRODUCTION

The motors which were fired during this research program utilized replaceable propellant grains which are placed in a reusable case and fired through a reusable nozzle. Two propellant formulations were fired; the first series of (9) grains were used as a control group to compare their propulsion efficiencies to efficiencies of an identical formulation previously fired at sea level. A second series of (6) grains of a formulation having higher energy were then fired to determine the delivered performance of this propellant when expanded to the low pressure (.08 psia) of high altitudes (116,000 ft).

II. FACILITIES UTILIZED

Data was recorded in digital format on a 192 channel Consolidated Systems Corporation tape recorder, in analog form on direct-inking Westronics recorders, and in analog form on a 36 channel Consolidated Engineering Corporation oscillograph. One 2-stage ejector system, driven by steam, and a 24-inch diameter cylindrical diffuser, which was driven by the rocket motor gas, evacuated the test cell of gases to provide the requested 100,000+ feet minimum pressure altitude. Thrust and pressures were sensed by strain-gage type transducers which were energized by direct current. The thrust mount and force measurement system were evaluated prior to use for this series of tests and found to be repeatable to .30% at the 90% confidence level and pressure measurements are repeatable to .5%. No firing programmer was used for these firings because only a single 28 VDC fire pulse was necessary and was initiated by the console operator.

A fault in the digital recorder was discovered during reduction of the digital format data to engineering units. The calibration record signals are not closely enough aligned on the tape which causes erroneous records to be made. A service contract is being prepared to obtain modification of this digital recorder system.

Cell pressure records provided by the Alphatron recorder lag actual cell pressures so greatly that a 2 second firing is completed before the recorder responds. This instrument will be replaced by a more accurate Baratron device which has a faster response and increased accuracy.

III. SIMULATED PRESSURE ALTITUDES

Vertical Test Cell (VTC) 1-42B will produce pressure altitudes as high as 150,000 feet by use of an engine-driven diffuser in series with up to three, 2-stage, steam-driven ejector systems which operate in parallel. During the firings of the BATES motors, one, 2-stage facility ejector and a cylindrical 24-inch diameter ejector-diffuser, were used. Simulated altitude was held well above the minimum requested 100,000 feet and all facility equipment functioned properly. Figure I shows the history of the motor and test facility pressures. The firing duration (1-2 seconds) was so short and the total gas generated (13 lb_m) so small a quantity in proportion to the cell and duct volume (30,000 ft^3) that cell pressure variations were less than .06 psia and ranged from a pressure altitude of 103,000 feet to 116,000 feet.

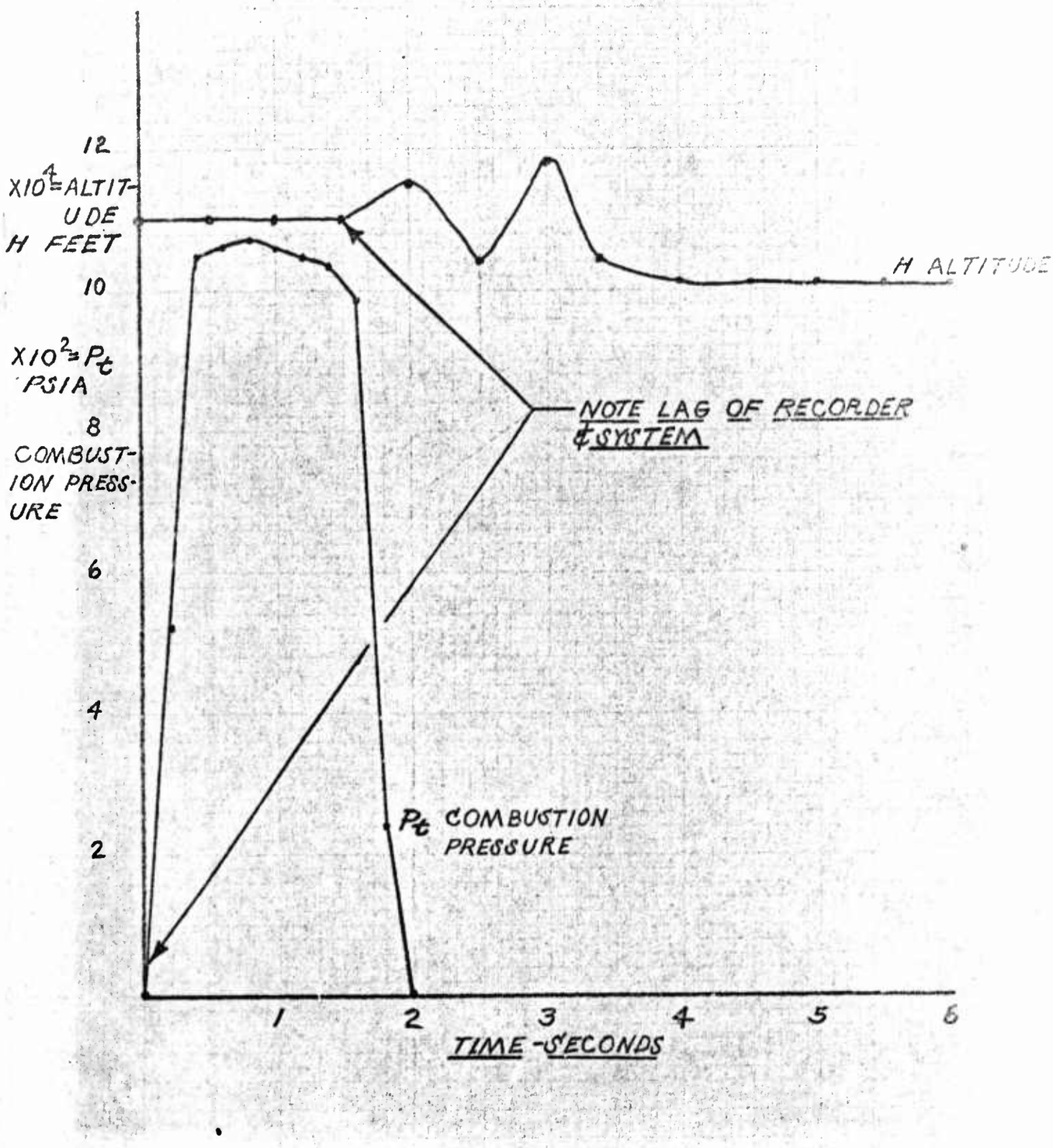


FIGURE 1 - SIMULATED ALTITUDE DURING MOTOR FIRING IN TEST CELL 1-42B

IV. ABLATIVE MATERIALS AS THERMAL AND ABRASIVE PROTECTION FOR DIFFUSERS

The cylindrical diffuser used for these tests is a section of water pipe which has no coolant jacket to aid in removal of heat energy. In a preceding firing of larger motors into the 44-inch diameter water-cooled (jacketed) diffuser, rocket gases burned through the wall of the diffuser which prompted a search for a satisfactory thermal and abrasion barrier to be used as a protective coating for the diffuser inlet. Several materials were applied to the impingement area of rocket gases in the diffuser used in these tests. These included epoxy resin, a paste made by RPRO of epoxy resin and graphite particles, a V-61 rubber compound intended to be used as liner material for rocket motor cases, Saueresin which is a patented ceramic material, and an asbestos-resin material which was supplied by Haveg-Reinhold (Santa Fe Springs, California). The approximately five-second duration of each pulse of this test series did not provide as severe a heat and abrasion situation as the earlier motor firing. The materials were applied and reacted as follows:

a. V-61 - troweled on - no measurable erosion.

b. Epoxy-carbon paste - troweled on - no measurable erosion.

c. Epoxy resin (only) - paint brush - no measurable erosion.

d. Sauresin - troweled on - no measurable erosion.

e. Asbestos-resin sheet - bolted - no measurable erosion.

The materials will be evaluated during firings in the January-June 1969 period which will impose more severe heat conditions because of longer firing durations, up to 500 seconds.

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